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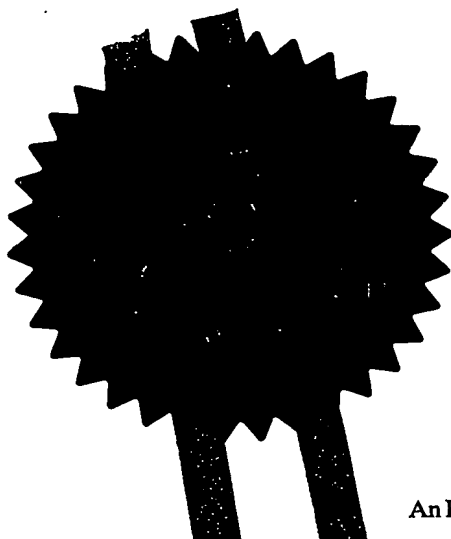
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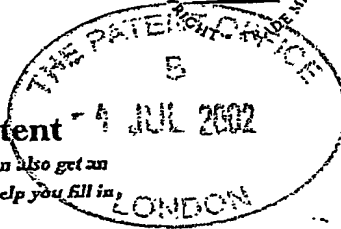
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1. Your reference

R071551PGB

2. Patent application number

(The Patent Office will fill in this part)

0215488.8

3. Full name, address and postcode of the or of each applicant (underline all surnames)

Delphi Technologies, Inc  
PO Box 5052, Troy  
Michigan 48007  
United States of America

7588320001

Patents ADP number (if you know it)

If the applicant is a corporate body, give the country/state of its incorporation

Delaware, United States of America

4. Title of the invention

FUEL INJECTION SYSTEM

5. Name of your agent (if you have one)

"Address for service" in the United Kingdom to which all correspondence should be sent (including the postcode)

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Country

Priority application number  
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7. If this application is divided or otherwise derived from an earlier UK application, give the number and the filing date of the earlier application

Number of earlier application

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8. Is a statement of inventorship and of right to grant of a patent required in support of this request? (Answer 'Yes' if:

Yes

- a) any applicant named in part 3 is not an inventor, or  
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# Patents Form 1/77

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Description 11

Claim(s) 2

Abstract

Drawing(s) 4

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Priority documents

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Statement of inventorship and right to grant of a patent (Patents Form 7/77)

Request for preliminary examination and search (Patents Form 9/77)

Request for substantive examination (Patents Form 10/77)

Any other documents (please specify)

11.

I/We request the grant of a patent on the basis of this application.

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Date

4 JULY 2002

12. Name and daytime telephone number of person to contact in the United Kingdom

Joanne S Pople 0121 643 5881

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DUPLICATE

## FUEL INJECTION SYSTEM

The invention relates to a fuel injection system for use in supplying high pressure fuel to a compression ignition internal combustion engine.

Known common rail fuel systems include an accumulator volume or rail which is charged with fuel at high pressure by means of a high pressure fuel pump. Fuel at high pressure is supplied by the common rail to a plurality of injectors, each of which is arranged to inject fuel into an associated engine cylinder.

It is desirable to be able to vary the injection characteristic of the injected fuel spray. In particular, for emissions purposes it is beneficial to provide a pilot injection of fuel at a relatively low injection rate followed by a main injection of fuel at a higher rate. A pilot/main injection sequence also has benefits for engine combustion noise. It is also thought to be of particular advantage to provide a main injection of fuel having a so-called "boot-shaped" injection rate. A boot-shaped injection rate characteristic comprises an initial relatively low injection rate of short duration immediately followed by a higher injection rate. Providing a higher rate main injection of fuel followed by a post injection of fuel is also known to provide emissions benefits.

By way of background to the present invention, WO 01/14726 A1 describes a common rail fuel system in which an accumulator volume or common rail is charged with fuel at high pressure by means of a high pressure fuel pump. Fuel within the accumulator volume is distributed to a plurality of injection nozzles, each of which has an associated intensifier arrangement. Each intensifier arrangement serves to further increase the pressure of fuel supplied from the common rail and delivers fuel at increased pressure to the associated injection nozzle through a high pressure supply line.

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Each injection nozzle has a valve needle which is biased towards a closed position in which it is seated against a valve seating by means of a spring. In order to commence injection, the valve needle is moved away from the seating, against the spring force, by varying fuel pressure within a control chamber arranged at a back end of the needle. The control chamber communicates continuously with the high pressure supply line and fuel pressure within the control chamber is controlled by means of a two-way nozzle control valve. The nozzle control valve is operable between an open position, in which the control chamber communicates with a low pressure drain, and a closed position in which communication between the control chamber and the drain is broken.

In order to provide an injection of fuel, the nozzle control valve is opened to permit fuel within the control chamber to escape to low pressure, thereby causing fuel pressure within the nozzle control chamber to be reduced. A point will be reached at which the force due to fuel pressure acting on thrust surfaces of the valve needle is sufficient to overcome the force due to fuel pressure within the control chamber acting in combination with the spring force, and the valve needle lifts from its seating. Closure of the valve needle is effected by closing the nozzle control valve to re-establish high pressure fuel within the control chamber.

A problem with the aforementioned system is that, when the nozzle control valve is opened to lift the valve needle, there is a continuous flow of high pressure fuel between the high pressure supply line and the low pressure drain, and therefore a proportion of high pressure fuel is wasted. The parasitic losses of the system are therefore relatively high.

It is an object of the present invention to provide an improved fuel injection system, which permits the fuel injection characteristic, and in particular the

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injection rate, to be varied and which overcomes or alleviates the aforementioned problem of the prior art.

According to the present invention there is provided a fuel injection system comprising;

a fuel source arranged to be charged with fuel by means of a high pressure fuel pump and for supplying fuel at a first injectable pressure level to a plurality of fuel injectors,

wherein each injector includes a delivery passage, a valve needle, which is engageable with a seating to control fuel injection, and a nozzle control valve for controlling fuel pressure within a control chamber of the nozzle so as to control movement of the valve needle, wherein the nozzle control valve has a first operating position in which the control chamber communicates with a low pressure drain and communication between the control chamber and the delivery passage is prevented and a second operating position in which the control chamber communicates with the delivery passage and communication between the control chamber and the low pressure drain is prevented,

and wherein each injector has an associated intensifier arrangement for increasing the pressure of fuel to be supplied to the injector to a second, injectable pressure level and including intensifier control valve means, which is operable to determine whether fuel injected to the engine is at the first or second injectable pressure level.

The present invention provides the advantage that the injection characteristic, and, in particular the injection pressure and hence injection rate, can be varied by operating the intensifier control valve means between first and second

states. It has been found that emission levels benefit from an injection event comprising a pilot injection of fuel at a relatively low injection rate, followed by a main injection of fuel at a higher rate. The present invention provides a convenient means of achieving this as the intensifier control valve means can be switched relatively rapidly to switch the injected pressure level between the first and second rates. The fuel system also enables a boot-shaped injection rate to be achieved, which is also found to have advantages for emissions levels.

It is a further advantage of the present invention that parasitic fuel losses are minimised, due to the provision of the three-way nozzle control valve. By providing the intensifier arrangement, the high pressure fuel pump for charging the accumulator volume need only be capable of pressurising fuel to a relatively low, injectable pressure.

In a preferred embodiment, the intensifier arrangement includes an intensifier piston having a first surface area exposed to fuel pressure within a pressure control chamber and a second surface area exposed to fuel pressure within an intensifier chamber, wherein the first surface area is greater than the second surface area, thereby to provide an increased fuel pressure level within the intensifier chamber.

The system further includes a non return valve arranged within a high pressure supply line through which fuel is supplied from the accumulator volume to the injector delivery passage.

Preferably, the accumulator volume is charged with fuel at a first pressure level of around 300 bar, in use, and the intensifier arrangement is arranged so as to provide fuel at a second pressure level in excess of 2000 bar.

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In one embodiment, the intensifier arrangement is arranged within a housing common to the associated injector. The common housing may be formed from several separate housing parts. In a further preferred embodiment, the intensifier control valve means includes a valve member which is substantially axially aligned with the intensifier piston within the common housing and/or with the valve needle.

The invention will now be described, by way of example only, with reference to the accompanying drawings in which:

Figure 1 is a schematic diagram of a fuel system of the present invention when in a first operating condition,

Figure 2 illustrates the system in Figure 1 when in a second operating condition,

Figure 3 shows the system in Figures 1 and 2 when in a third operating condition,

Figure 4 is a graph to show the injection rate for a pilot injection of fuel at a first fuel pressure level,

Figure 5 is a graph to show the injection rate for a main injection of fuel at a second, higher fuel pressure level, and

Figure 6 shows a practical embodiment of a part of the fuel system in Figures 1 to 3.

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Referring to Figure 1, the fuel system of the present invention includes an accumulator volume or common rail 10, which is charged with fuel at high pressure by means of a high pressure fuel pump 12. Typically, fuel pressure within the common rail is pressurised to a level of around 300 bar. The fuel pump 12 receives fuel at relatively low pressure through an inlet 14. The common rail 10 supplies fuel at a first pressure level to a high pressure supply line 16, and is arranged to deliver fuel to a delivery line or delivery passage 20 of an associated fuel injector, referred to generally as 22. In practice a plurality of fuel injectors will be provided, one for each engine cylinder, but for simplicity only one of these will be described in detail.

The high pressure supply line 16 is provided with a non return valve 18 including a valve member 19 which is engageable with a non return valve seating to control flow through the high pressure supply line 16. The non return valve 18 is provided with a spring 18a which tends to close the non return valve, but upon pressurisation of fuel within the common rail 10 a force is applied to the non return valve member 19 which serves to urge the non return valve into an open position, against the force of the spring 18a, to permit fuel to flow through the high pressure supply line 16 to the delivery line 20. Should fuel pressure within the delivery line 20 increase beyond a predetermined level, the non return valve member 19 will be urged to close to prevent a return flow of fuel from the delivery line 20 to the common rail 10.

The delivery line 20 communicates directly with a delivery chamber 24 of the fuel injector 22, and with a low pressure drain under the control of a nozzle control valve 26. The nozzle control valve 26 is operable under the control of an actuator (not shown), for example an electromagnetic or piezoelectric actuator, so as to control communication between a control chamber 28 of the injector and the low pressure drain. The injector 22 further includes a valve

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needle 30, which is urged towards a valve needle seating (not shown) by means of a valve needle spring 30 acting in combination with the hydraulic force due to fuel pressure within the control chamber 28. When the valve needle 30 is in its seated position, fuel injection into the engine cylinder does not take place.

The nozzle control valve 26 is actuatable between a closed position, in which the delivery line 20 communicates with the control chamber 28 and communication between the control chamber 28 and the low pressure drain is broken, and an open position in which communication between the control chamber 28 and the low pressure drain is open and fuel flow from the delivery line 20 into the control chamber 28 is prevented.

The common rail 10 also supplies fuel to a pressure control chamber 32 of an intensifier arrangement, referred to generally as 34. The intensifier arrangement 34 includes an intensifier control valve means 36 having an actuatable valve member (not shown), and further including an intensifier piston 38 having a first end 38a exposed to fuel pressure within the pressure control chamber 32 and a second end 38b exposed to fuel pressure within an intensifier chamber 40 at the end of the piston 38 remote from the pressure control chamber 32. A further chamber 42 intermediate the pressure control chamber 32 and the intensifier chamber 40 communicates with the low pressure drain and permits any fuel leakage from the pressure control chamber 32 and/or the intensifier chamber 40 past the piston 38 into the further chamber 42 to escape to low pressure so as to prevent the occurrence of a hydraulic lock.

The first end 38a of the piston 38 has a larger effective surface area exposed to fuel within the pressure control chamber 32 than the area of the second surface 38b exposed to fuel within the intensifier chamber 40. The intensifier arrangement 34 therefore provides a hydraulic amplification effect, to increase

fuel pressure within the intensifier chamber 40 to a second pressure level, which is higher than the pressure level within the common rail 10. Typically, fuel pressure within the intensifier chamber 40 is increased to a level in excess of 2000 bar.

The fuel system in Figure 1 permits fuel to be injected into the engine either at the first relatively high pressure level within the common rail 10, or at the second, higher pressure level within the intensifier chamber 40, depending upon the position of the intensifier control valve 36. In use, with the intensifier control valve 36 in a closed position (as shown in Figure 1), fuel within the common rail 10 is unable to flow through the intensifier control valve 36 into the pressure control chamber 32. Fuel pressure within the pressure control chamber 32 therefore remains at a relatively low level. The flow of fuel from the common rail 10 urges the non return valve 18 open, so that fuel from the common rail 10 is supplied through the high pressure supply line 16, into the delivery line 20 of the injector. In this operating condition, fuel pressure within the intensifier chamber 40 is at the first pressure level supplied by the rail 10.

With the nozzle control valve 26 in its closed position (as shown in Figure 1), a supply of high pressure fuel flows into the control chamber 28 at the back of the valve needle 30 and, in combination with the force of the spring 30, serves to urge the valve needle 30 into engagement with its seating to prevent injection.

If it is required to inject fuel at the first pressure level, the nozzle control valve 28 is moved to its open position to close communication between the delivery line 20 and the control chamber 28, and to open communication between the control chamber 28 and the low pressure drain. In such circumstances fuel within the control chamber 28 is able to flow to low pressure, thereby reducing

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the force acting on the back end of the valve needle 30. As a consequence of this the valve needle 30 is urged away from its seating due to high fuel pressure within the delivery chamber 24 to permit fuel injection to the engine at the first pressure level.

To terminate injection at the first pressure level, the nozzle control valve 26 is returned to its closed position, breaking communication between the control chamber 28 and the low pressure drain and opening communication between the delivery line 20 and the control chamber 28. High pressure fuel is re-established within the control chamber 28 to re-seat the valve needle 30.

Figure 2 shows the fuel system of Figure 1 when in the first injecting state, in which the valve needle 30 is lifted from its seating and fuel at the first pressure level is injected to the engine.

If it is required to inject fuel at the second, higher level, the intensifier control valve 36 is actuated to move into an open position in which fuel at the first pressure level is supplied to the pressure control chamber 32. Fuel pressure within the pressure control chamber 32 is therefore increased, and the piston 38 is urged in a downward direction (as shown in Figure 3). Due to the differential area between the first surface 38a of the piston 38 exposed to fuel pressure within the pressure control chamber 32 and the area 38b of the second end of the piston 38 which is exposed to fuel pressure within the intensifier chamber 40, fuel pressure within the intensifier chamber 40 is caused to increase to a second, higher pressure level. It will be appreciated that the differential areas of the first and second ends 38a, 38b of the piston 38 provide a hydraulic amplification effect to increase fuel pressure in the intensifier chamber 40 to the second pressure level. Typically, pressure within the intensifier chamber 40 is increased to a level in excess of 2,000 bar, and preferably between 2400 and 2500 bar.

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As fuel pressure within the intensifier chamber 40 is increased, the non return valve member 19 will be urged closed, thereby terminating the flow of fuel between the high pressure supply line 16 and the delivery line 20, and trapping higher pressure fuel within the delivery line 20. In order to inject fuel at this second, higher pressure level, the nozzle control valve 26 is opened to relieve fuel pressure within the control chamber 28, thereby causing the valve needle 30 to lift, as described previously.

The present invention therefore provides a means of injecting fuel at two, high pressure levels under the control of the intensifier control valve 36. The system is particularly beneficial in that it enables a pilot injection of fuel to be delivered at a lower injection rate followed by a subsequent, main injection of fuel at a higher rate. It has been found that this sequence benefits the emissions levels and provides advantages for engine combustion noise.

Figures 4 and 5 show an example of the injection rate for a pilot injection of fuel and for a main injection of fuel respectively. In Figure 5, the main injection of fuel has a so-called "boot-shaped" injection rate, comprising an initial square shaped injection rate followed by a rising injection rate. In order to achieve the boot-shaped main injection, the intensifier control valve 36 is moved from its closed state (as shown in Figure 2) to its open state (as shown in Figure 3) without re-seating the valve needle 30 (i.e. keeping the nozzle control valve 26 open).

It will be appreciated that alternative combinations or sequences of a lower rate injection and a higher rate injection are also possible using the system in Figures 1 to 3. For example, a boot-shaped main injection of fuel may be followed by a lower rate post injection of fuel, or followed by a late post injection of fuel for after treatment purposes.

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As the common rail 10 need only be charged to a moderately high pressure (e.g. 300 bar) the demands on the high pressure pump are reduced. Furthermore, as the intensifier arrangement 34 is driven by this moderate rail pressure, without the need for a cam drive, the limitation on injection timing in known systems is avoided.

Figure 6 shows a practical embodiment of a part of the fuel system in Figures 1 to 3, in which the nozzle control valve 26, the intensifier arrangement 34 and the intensifier control valve 36 are all housed within a common housing. The intensifier arrangement 34 is housed within a first housing part 50 through which a part of the high pressure fuel line 16 extends. The first housing part 50 abuts a second housing part 52 through which the high pressure fuel line 16 also extends. The non return valve 18 is mounted within a region of the high pressure supply line 16 within the second housing part 52. The intensifier valve 36 is housed within a third housing part 54 in abutment with the end of the first housing part 50 remote from the second housing part 52. The valve member of the intensifier valve (identified as 36a in Figure 6) is axially aligned with the intensifier piston 38 and the valve needle 30. The arrangement of parts shown in Figure 6 is particularly advantageous as it is relatively compact and can easily be incorporated into existing engine designs.

## CLAIMS

## 1. A fuel injection system comprising;

a fuel source arranged to be charged with fuel by means of a high pressure fuel pump and for supplying fuel at a first injectable pressure level to a plurality of fuel injectors,

wherein each injector includes a delivery passage, a valve needle, which is engageable with a seating to control fuel injection, and a nozzle control valve for controlling fuel pressure within a control chamber of the nozzle so as to control movement of the valve needle, wherein the nozzle control valve has a first operating position in which the control chamber communicates with a low pressure drain and communication between the control chamber and the delivery passage is prevented and a second operating position in which the control chamber communicates with the delivery passage and communication between the control chamber and the low pressure drain is prevented,

and wherein each injector has an associated intensifier arrangement for increasing the pressure of fuel to be supplied to the injector to a second injectable pressure level and including intensifier control valve means, which is operable to determine whether fuel injected to the engine is at the first or second injectable pressure level.

2. A fuel injection system as claimed in Claim 1, wherein the intensifier arrangement includes an intensifier piston having a first surface area exposed to fuel pressure within a pressure control chamber and a second surface area exposed to fuel pressure within an intensifier chamber, wherein the first surface

area is greater than the second surface area, thereby to provide an increased fuel pressure level within the intensifier chamber.

3. The fuel injection system as claimed in Claim 1 or Claim 2, including a non return valve arranged within a high pressure supply line through which fuel is supplied from the accumulator volume to the injector delivery passage.

4. The fuel injection system as claimed in any of Claims 1 to 3, whereby the accumulator volume is charged with fuel at a first pressure level of around 300 bar, in use.

5. The fuel injection system as claimed in any of Claims 1 to 4, whereby in the intensifier arrangement is arranged so as to provide fuel at a second pressure level in excess of 2000 bar.

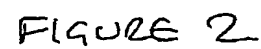
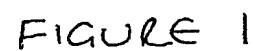
6. The fuel injection system as claimed in any of Claims 1 to 5, wherein the intensifier arrangement is arranged within a housing common to the associated injector.

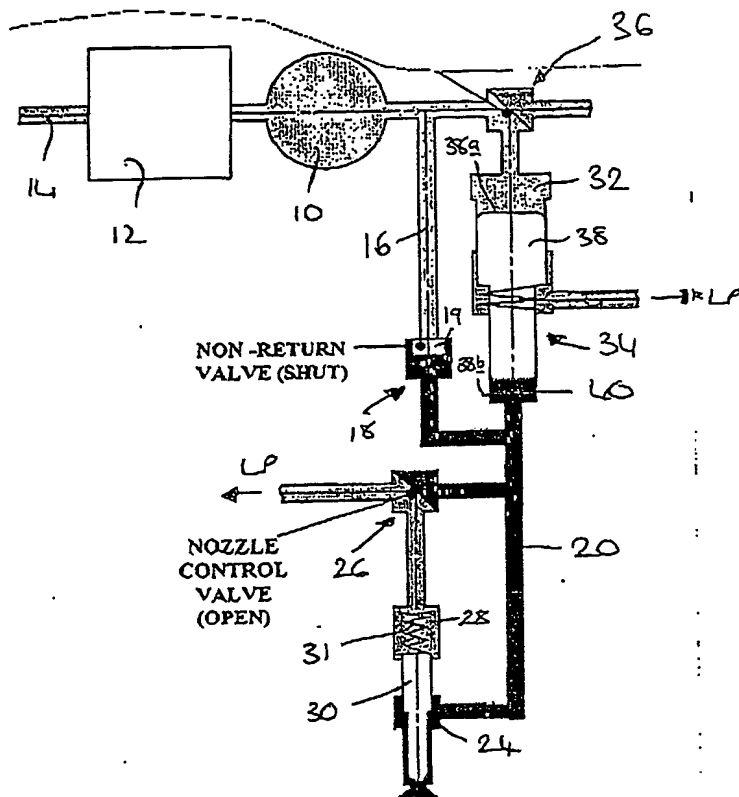
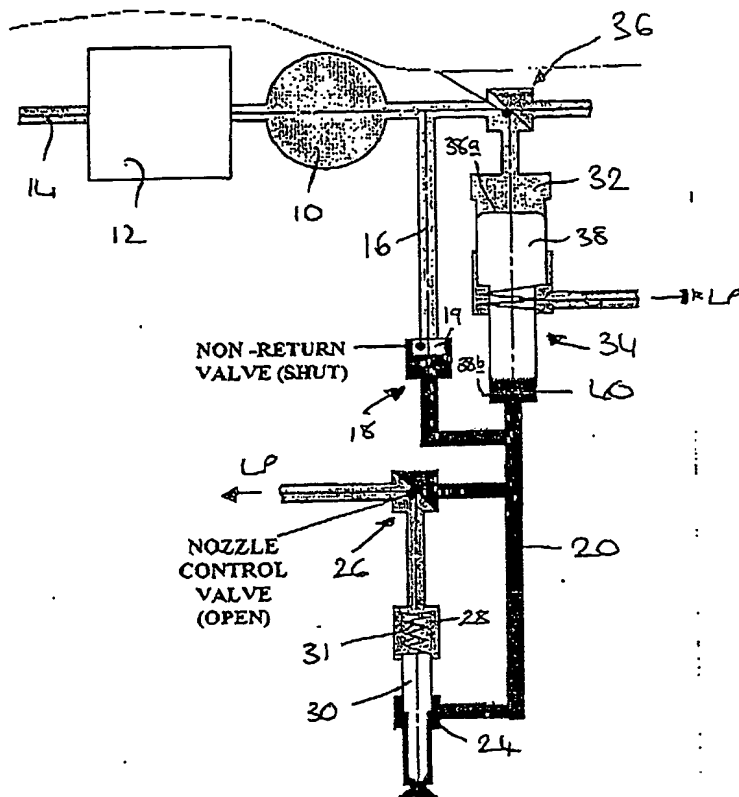
7. The fuel injection system as claimed in Claim 6, wherein the common housing is formed from two or more separate housing parts.

8. The fuel injection system as claimed in Claim 6 or Claim 7, wherein the intensifier control valve means includes a valve member which is substantially axially aligned with the intensifier piston within the common housing.

9. The fuel system substantially as herein described with reference to the accompanying drawings.

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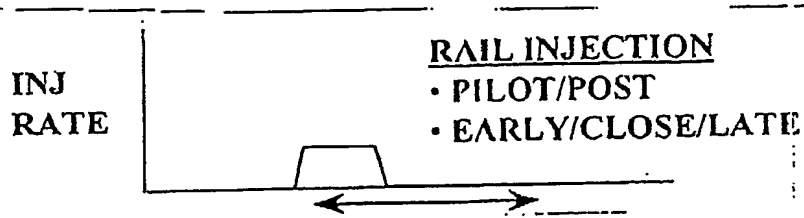


FIGURE 4.

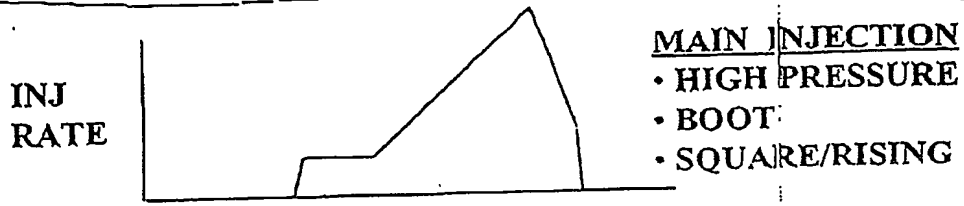


FIGURE 5

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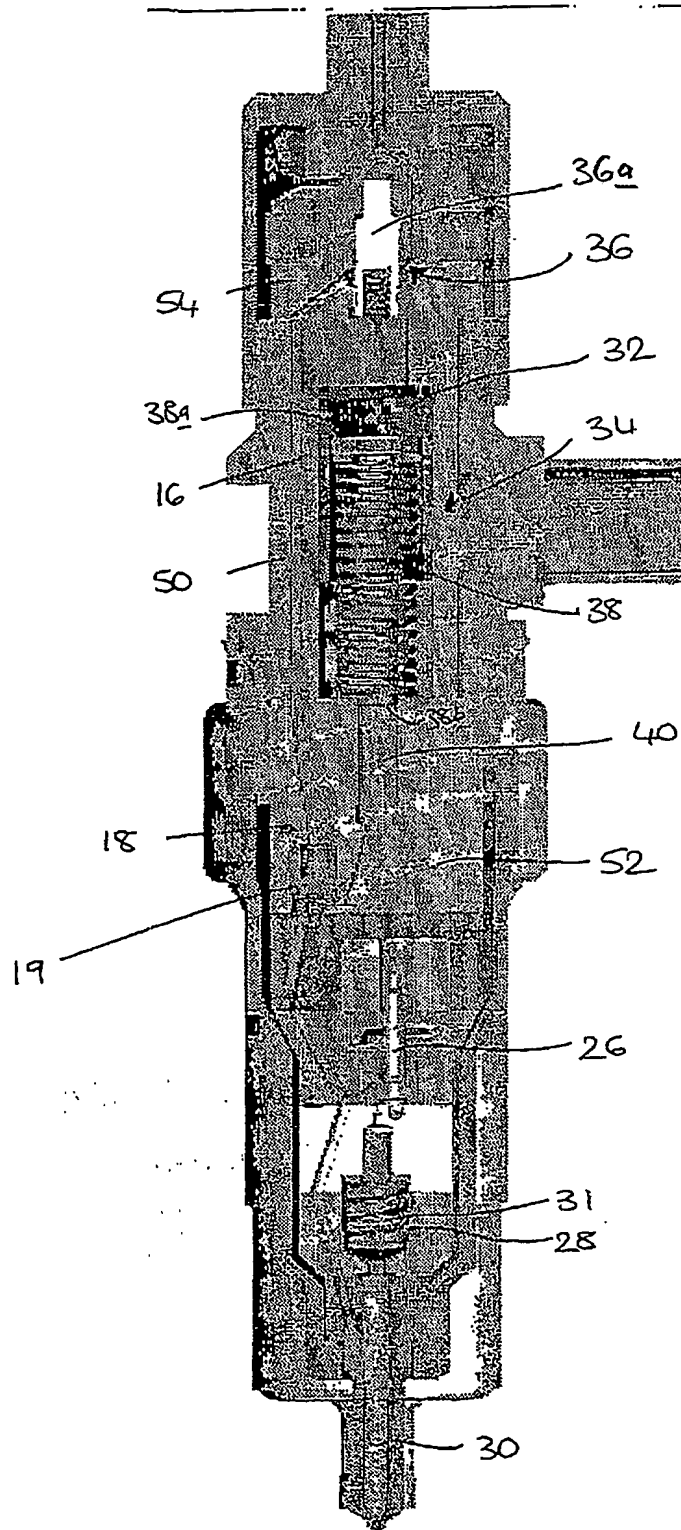


FIGURE 6

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